NeoBiota 29: 53–62 (2016)
doi: 10.3897/neobiota.29.7230
http://neobiota.pensoft.net

SHORT COMMUNICATION

A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

Invasive *Acacia mearnsii* De Wilde in Kunming, Yunnan Province, China: a new biogeographic distribution that Threatens Airport Safety

Min Liu[1,2], Mingyu Yang[1], Ding Song[3], Zhiming Zhang[1], Xiaokun Ou[1]

1 *Institute of Ecology and Geobotany, Yunnan University, 2# Northern Green-Lake Road, Kunming 650091, China* **2** *Yunnan Key Laboratory of International Rivers and Transboundary Eco-security, Yunnan University, 2# Northern Green-Lake Road, Kunming 650091, China* **3** *Kunming University of Science and Technology, 727# South Jingming Rd., Chenggong 650500, China*

Corresponding author: *Xiaokun Ou* (xkou@ynu.edu.cn)

Academic editor: *B. Murray* | Received 19 November 2015 | Accepted 25 January 2016 | Published 16 March 2016

Citation: Liu M, Yang M, Song D, Zhang Z, Ou X (2016) Invasive *Acacia mearnsii* De Wilde in Kunming, Yunnan Province, China: a new biogeographic distribution that Threatens Airport Safety. NeoBiota 29: 53–62. doi: 10.3897/neobiota.29.7230

Abstract

Acacia mearnsii De Wilde is on the top 100 of the world's most invasive alien species and has successfully invaded many areas around the world. However, its distribution and expansion is seldom reported in China. This study for the first time conducted a survey on the new distribution of *A. mearnsii* at the Kunming Changshui Airport (Yunnan Province, China), through monitoring on population characteristics (number, density, height and ground diameter) and spatial distribution (spread distance). Our survey results show that *A. mearnsii* has spread rapidly across the airport. This study discusses three factors of environmental factors, human disturbance and weed characteristics behind this successful invasion. The species invasion has a strong potential to change the local vegetation structure, enhances the probability of bird strikes at the airport, and is vulnerable to invade new biogeographic regions if it is not controlled. Currently, eradication combined with mechanical control is considered to be the best option for control. Our study helps improve awareness about the potential risk of *A. mearnsii* invasion in other airports around China and the world.

Keywords

Acacia mearnsii, plant invasion, new distribution, birdstrike prevention, management strategy

Introduction

Invasive plant species are increasingly threatening biodiversity and ecosystem functioning around the world. They are often referred to as naturalized alien (exotic or non-native) plants that establish and maintain their population by self-reproduction and self-diffusion at considerable distances from the parent plants, and have become harmful species, to some extent, or have had a negative influence on humans (Lamarque et al. 2011; Pyšek et al. 2004; Richardson et al. 2000). These species are characterized by easy establishment, fast growth and high propagule pressure (Dodet and Collet 2012).

Acacia mearnsii De Wilde (black wattle) is native to Australia, and is listed as being among "100 of the world's worst invasive alien species" by the World Conservation Union (Lowe et al. 2000; Luque et al. 2014). The species has already been disseminated globally for more than 150 years owing to its multiple uses (e.g., leather, resins, fuel, paper, medical applications, etc.) (Castro-Dièz et al. 2011; Richardson et al. 2011). The Global Invasive Species Database (GISD) reported the species has become an invasive problem in France, India, Israel, Italy, New Zealand, Portugal, Reunion, South Africa, Spain, Uganda and United States. Its invasiveness threatens the native environment by competing with indigenous vegetation, replacing grass populations, and reducing native biodiversity, which causes large economic losses to these regions (http://www.issg.org/database).

In the 1950s, *A. mearnsii* was first introduced into China for afforestation and commercial forestry (Fu 2005; Griffin et al. 2011). However, after that, the expansion of this species was seldom reported in China. In recent years, a few studies reported that 10 provinces in China have already recorded *A. mearnsii* (including Yunnan Province) (Cai et al. 2009; Feng et al. 2010; Fu 2005; Ke et al. 2010; Li et al. 2007). However, there is not sufficient evidence to show *A. mearnsii* has turned into an invasive species in these provinces.

At the Kunming Changshui international airport (here after referred to as Changshui airport), Yunnan, China, we discovered that *A. mearnsii* populations have appeared by self-renewal in recent years. The trees attract many birds to rest on them, which increases the opportunities for bird strike at the airport (Gallagher et al. 2011; Gibson et al. 2011; Li 2014; Li et al. 2011; Xu et al. 2011). We undertook an *A. mearnsii* invasion survey, which is the first time in China that a detailed monitoring investigation of this species has been performed. The aims of this study were thus to determine: (1) could *A. mearnsii* become an invasive species in China, especially in areas with similar climates (such as Kunming); (2) what are the potential risks of *A. mearnsii* invasion at the airport where bird strike prevention measures are needed to ensure flight safety; (3) which effective management options can be adopted for the treatment of *A. mearnsii* invasion?

Materials and methods

Acacia mearnsii

Acacia mearnsii belongs to the Mimosaceae (affiliated to the Leguminosae), and is a heliophile, evergreen, nitrogen fixing, fast growing tree species. A detailed description is provided by De Wit et al. (2001) and Sherry (1971). The species grows in disturbed, mesic habitats and thrives in a range of climates, including warm temperate dry climates and moist tropical climates (http://www.issg.org/database). Duke (1983) reported that it can tolerate an annual precipitation of between 660–2280 mm, an annual mean temperature of 14.7–27.8 °C, and a pH of 5.0–7.2. The GISD says that it does not grow well on very dry or poor soils, however, Crous et al. (2012) reported that it is highly drought-tolerant, able to withstand low minimum water potentials, and can utilize a large proportion of soil water.

Study area

Changshui airport is located in the north-eastern part of Kunming (the capital city of Yunnan Province) (Fig. 1a, b). It is the fourth largest airport in China. It handles 20 million passengers each year and has 275 routes to 134 cities, such as Beijing,

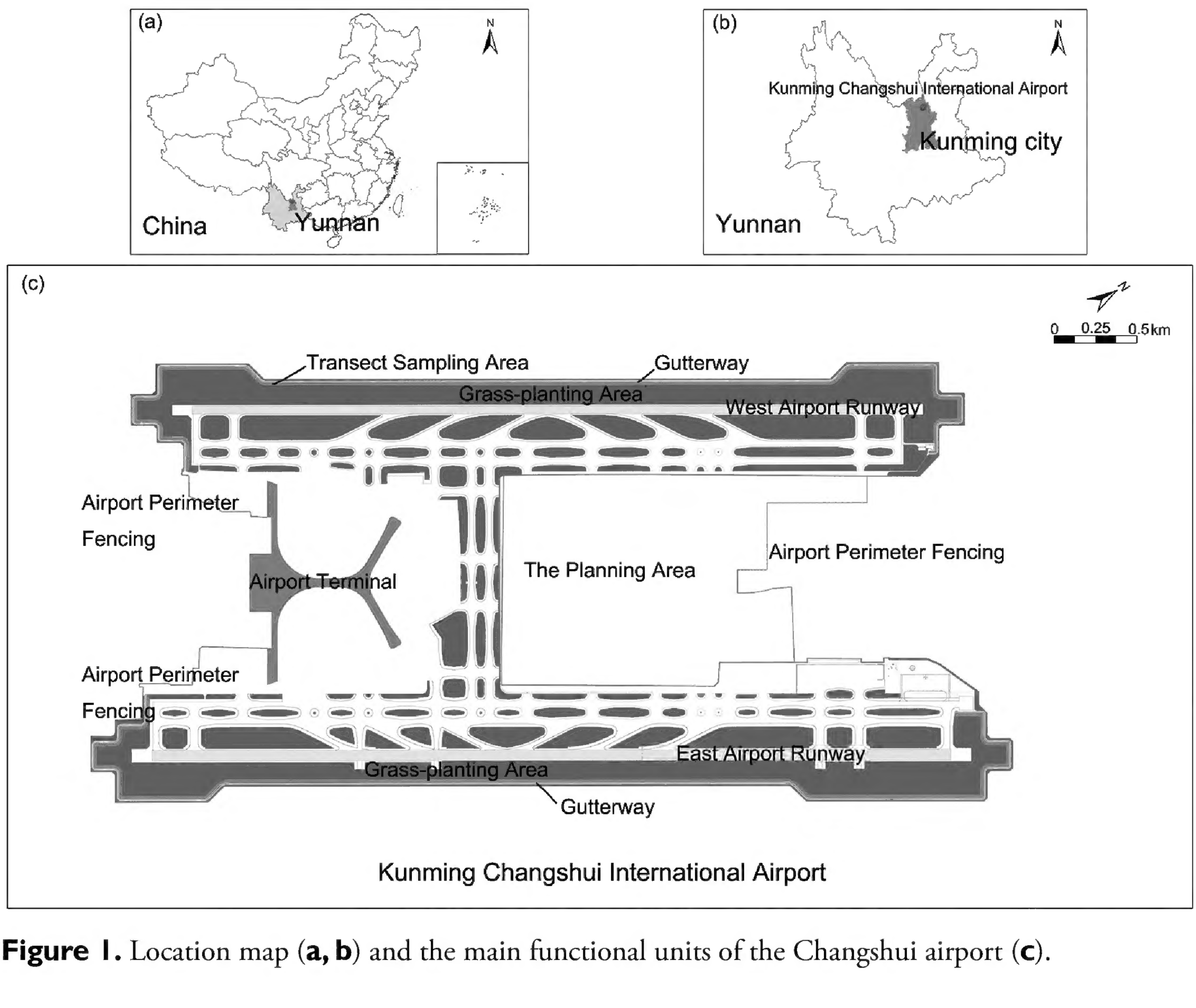

Figure 1. Location map (**a, b**) and the main functional units of the Changshui airport (**c**).

Shanghai, Singapore and Paris. The total area of Changshui airport is 22.97 km^2, its functional units are composed of an airport terminal, two runways (East and West), grass-planting area and the planning area (area for future development) (Fig. 1c). The grass-planting area of the airport was established in 2012 where grassy herbaceous plants (mainly graminoid) are cultivated. The airport is surrounded by farmland, secondary forest and villages. It is located in a subtropical semi-humid monsoon climate zone, with an average temperature of 15 °C and an average precipitation of 1035 mm. The climate features are quite similar to the original habitats of *A. mearnsii* in Australia (Duke 1983; Fu 2005; Gao and Ren 1989; http://www.issg.org/database).

Survey method

The pilot survey in early 2013 showed that *A. mearnsii* seedlings mostly had appeared in the grass-planting area near two gutterways and the planning area within the airport. Considering flight safety, the airport authority approved the use of the grass area around the west gutterway as our sample area. In this context, we conducted 12 surveys, twice a month, in the sample area from June 2013 to November 2013. Two line transects along the gutterway (6.2 km long, see Fig. 1c) in west grass-planting area were established. Quadrat plots (5 × 5 m) were used as the secondary unit for surveys, with a 100 m interval between each plot. The number, height and ground diameter of *A. mearnsii* were recorded in each plot. The dispersal rate was also estimated by measuring the diffusion distance of new seedlings of *A. mearnsii* along two transects during the survey period.

Results

Invasion of *A. mearnsii*

The *A. mearnsii* populations first appeared in the south side of the west gutterway in May 2013 and spread slowly. In the following months when rainfall became abundant (i.e., July and August), the spread of *A. mearnsii* increased rapidly and most of them formed into relatively dense populations. They then also appeared in the north side of the west gutterway in August. Fig. 2 shows the extent of *A. mearnsii* invasion within the grass-planting area near the west gutterway. In the south side of gutterway, there were 400 m of *A. mearnsii* populations through the initial measurement in June. The diffusion rate was fastest in August, and the distance increased up to 1100 m with 400 m of these new seedlings. The diffusion continued to the west of the gutterway with 200, 300 and 200 m, respectively, from September to November. During the whole study period, the black wattle seedlings had totally spread to 1800 m with an average rate of 300 m per month. In the north side of gutterway, the new population distribution of *A. mearnsii* with 200 m was measured in August, and spread with 150 m to both ends of the gutterway in September. The last increase with 100 m in east side of the gutterway was found in October.

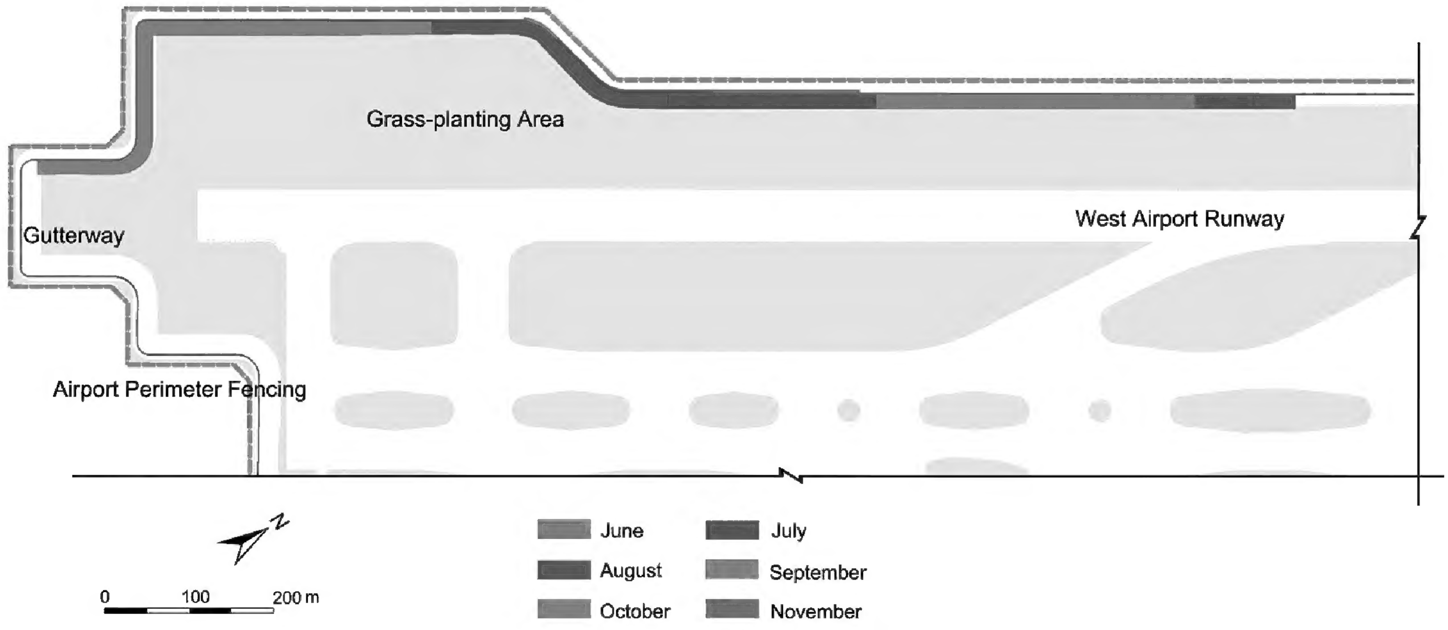

Figure 2. The distribution of *A. mearnsii* in the grass-planting area near the west gutterway at Changshui airport (June-November 2013).

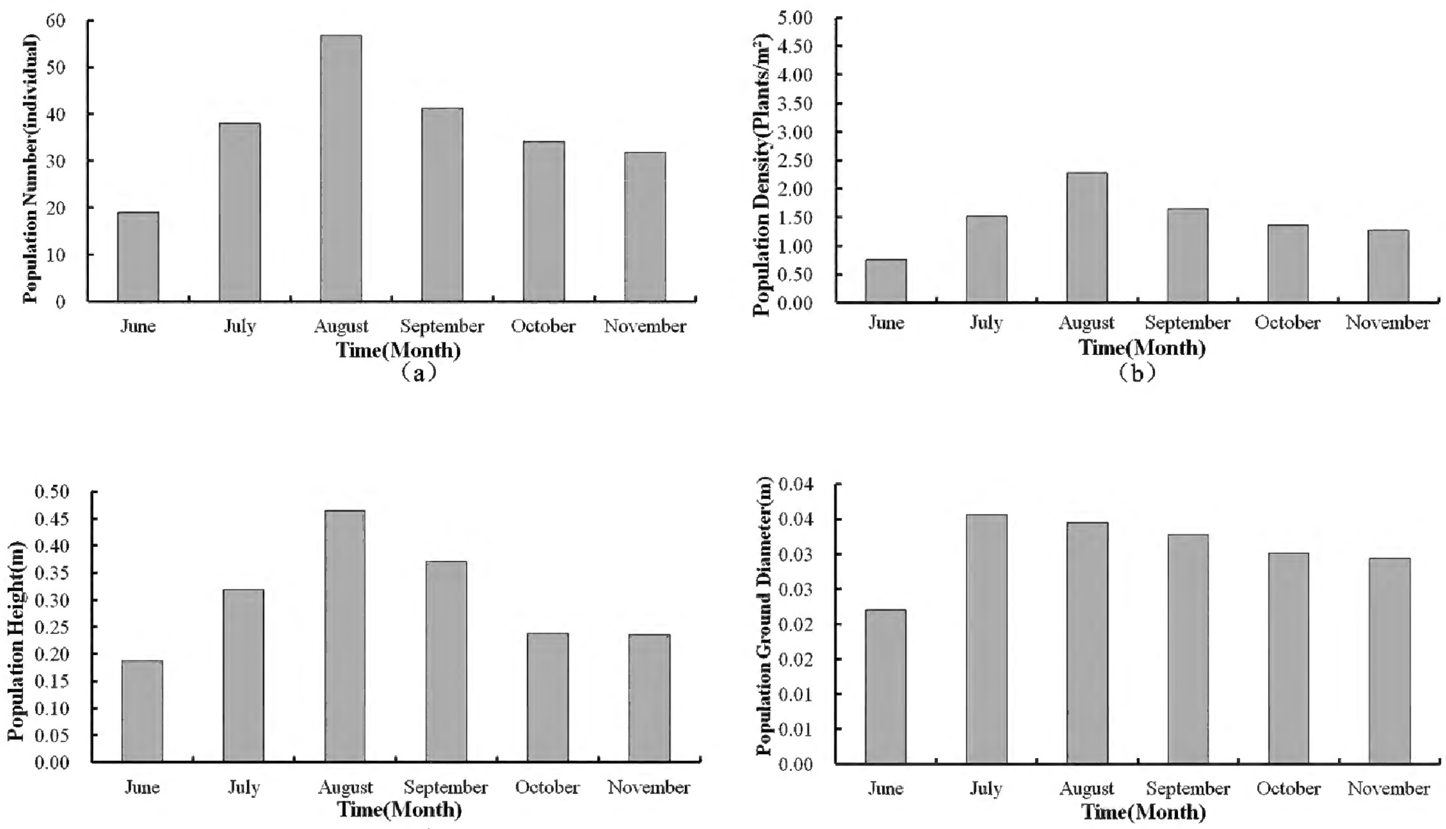

Figure 3. The population characteristics of *A. mearnsii* on mean population number (**a**), mean population density (**b**), mean population height (**c**) and mean population ground diameter (**d**) for plots in the west transect sampling area at Changshui airport.

Population characteristics of *A. mearnsii*

Plot-average data are shown in Fig. 3. Fig. 3(a) shows the average number of *A. mearnsii* species each month during the survey period. The population number reached a maximum in August, and the average number of trees per plot was 37 and the maximum number was 268. Fig. 3(b) shows the average sample density. Similarly, In

August it reached the highest density peak. The average density of *A. mearnsii* was 1–3 plants/m^2. In the denser areas, it was up to 10 plants/m^2, and the area had begun to resemble a wood. Fig. 3(c) shows the average sample heights were 19–47 cm. Most of the trees in the survey area were over 1 m high and the maximum height of *A. mearnsii* was up to 1.35 m in August. Fig. 3(d) reflects the mean diameter (ground diameter) of *A. mearnsii,* which ranges from 2.2 cm to 3.56 cm, and some seedlings increased their diameter more than 10 cm.

Discussion

Local invasion rate

Our investigation clearly demonstrates a successful invasion of *A. mearnsii* in the grass-planting area near the west gutterway at Changshui airport. The invasions have also appeared in other sites of the airport, such as in the grass-planting area near east gutterway and in the planning area of the airport. The data also show that the black wattle had an extraordinary pace of expansion at the survey area, which was reflected in the diffusion distance and in the population characteristics. The population overall diffused to 1800 m in the south side of the gutterway from June to November and 450 m in the north side of the gutterway from August to November. Population features (such as number, density, height and ground diameter) showed that the species had a very high growth rate. They increased dramatically in June and reached the peak in August, then decreased after 3 months, which exactly corresponds to the pattern of local rainfall. It should be note that these increased growths are partially flatted or slowed down by human disturbance. In order to prevent bird strikes, the frequent pruning works are practiced by airport staff and they clean up the larger and higher plants artificially at the airport, including many *A. mearnsii* seedlings in our survey area. However, despite this pruning, *A. mearnsii* populations still showed a rapid diffusion over the grass-planting area near the gutterway of the airport. With such a trend, *A. mearnsii* would become woodland in the near future and the whole grass-planting area of airport would be threatened.

Possible factors affecting invasion success

Explanations for *A. mearnsii* invasions have received attention in some studies (Dodet and Collet 2012; Donaldson et al. 2014; Lamarque et al. 2011; Low 2012). We identify a number of factors that are possible for the successful invasion by *A. mearnsii* at the Changshui airport, and group them into environmental factors, human disturbance and weed characteristics. Dodet and Collet (2012) highlighted that invasion may become effective only when environmental conditions allow the species to express their potential for invasion. In this case study, the land claimed as the airport were villages, farmland and planted forests (including planted black wattle forests) prior to the con-

struction of the airport in 2007, which probably resulted in extensive *A. mearnsii* seed banks that were spread and concentrated in the grass-planting area and in the planning area. Secondly, the species is highly adapted to the habitat because it has similar climate conditions to its natural habitat, which leads to high growth performance and an ability to become the dominant population. Thirdly, the on-going flight activities can take more seeds of *A. mearnsii* into the airport environment, either by flight flows or human/plane attachments. Meanwhile, interference by construction activities enhances invasion ability of *A. mearnsii*, because it can help break seed dormancy underground. Finally, the weedy characteristics are also key drivers of invasive success (Gibson et al. 2011; Low 2012), such as long-lasting inflorescences, a variety of dispersal pathways, the ability to re-sprout and germinate in abundance following disturbance, and high growth rates. All result in the emergence of a large number of tree seedlings after environmental adaptation in grass-planting area at the airport. However, uncertainty still remains as to the relative importance of environmental factors and species traits when determining the propensity of *A. mearnsii* at the Changshui airport to become invasive, and this needs to be further studied.

Risk assessment and management implications

Acacia mearnsii grows quickly and spreads rapidly in our study area. The species can radically change local vegetation structure, such as converting grass-planting area into woodland, or even forest (if there are no control measures) with this single dominant species. In addition, woodland or forest could enhance bird abundance and increase the probability of bird strike events (Li et al. 2010; Liao et al. 2012; Sandström et al. 2006; Tilghman 1987; Xu et al. 2011), which have been upgraded to an "A" class air disaster risk by the FAI (Federation Aeronautique Internationale). The detailed study of bird abundance for Changshui airport in 2013 showed there were 34 bird species often stay on or around the *A. mearnsii* trees, including *Passer montanus*, *Carduelis ambigua*, *Alauda gulgula*, *Motacilla alba*, and *Ardeola bacchus* (Bird Strike Prevention Office of Kunming Changshui International Airport 2013; Li 2014). In this context, invasions by *A. mearnsii* species will pose a potential threat to bird strikes at the airport.

The whole grass environment at the airport is vulnerable to invasion by the current population of black wattle if it is not controlled, and the populations will continue to spread or invade new biogeographic regions. Therefore precautionary risk assessment and adaptive management towards this species in the study area should be undertaken so that the negative impact and harm can be limited. At the airport, the *A. mearnsii* populations are in the early stages of invasion, and appropriate mix of available management methods should be employed to maximize their effect. So eradication combined with mechanical control is an effective option at current stage (van Wilgen and Richardson 2014). This is helped by the fact that the tree populations are localized and the trees themselves are kept in small. For the stages when trees grow up, mechanical control before flowering and seed maturity should be adopted to eliminate

their further dispersal. Finaly, promoting education and awareness of the dangers of *A. mearnsii* invasion is also needed to prevent further expansion of this species in the region (van Wilgen and Richardson 2014).

Conclusions

This study has shown that *A. mearnsii* has successfully invaded areas inside Changshui airport. The populations continue to spread at a rapid rate, and may invade new areas and change local ecosystem. Furthermore, the rapid distribution of *A. mearnsii* poses an increased threat to airport flights. These results imply that eradication, combined with an education program, need to be proposed. The rapid invasion of *A. mearnsii* at the study area highlights the potential risks to other airports in tropical and warm temperate areas of China or around the world. We therefore suggest detailed monitoring and assessment of *A. mearnsii* species should be carried out in these regions.

Acknowledgments

The authors express their gratitude to the Bird Strike Prevention Office of Kunming Changshui International Airport for assisting with the field surveys. The authors appreciate Juntao Liao, Shaoji Hu, and Li Zhang for their support during the data collection. The authors appreciate International Science Editing for providing language help. We also thank the anonymous reviewers for their constructive comments. The research was funded by a research grant (No. 41401641) from the National Natural Science Foundation of China.

References

Bird Strike Prevention Office of Kunming Changshui International Airport (2013) The ecological research report on bird strike prevention for Changshui airport of 2013. Unpublished. [In Chinese]

Cai Y, Luo Z, LEE L, Zou W, Ding B (2009) Population Structure and Recruitment of *Acacia mearnsii* in Wenzhou [J]. Bulletin of Science and Technology 6: 758–764. doi: 10.3969/j.issn.1001-7119.2009.06.012 [In Chinese]

Castro-Díez P, Godoy O, Saldaña A, Richardson DM (2011) Predicting invasiveness of Australian acacias on the basis of their native climatic affinities, life history traits and human use. Diversity and Distributions 17: 934–945. doi: 10.1111/j.1472-4642.2011.00778.x

Crous CJ, Jacobs SM, Esler KJ (2012) Drought-tolerance of an invasive alien tree, *Acacia mearnsii* and two native competitors in fynbos riparian ecotones. Biological invasions 14: 619–631. doi: 10.1007/s10530-011-0103-y

De Wit M, Crookes D, Van Wilgen B (2001) Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion. Biological invasions 3: 167–178. doi: 10.1023/A:1014563702261

Dodet M, Collet C (2012) When should exotic forest plantation tree species be considered as an invasive threat and how should we treat them? Biological invasions 14: 1765–1778. doi: 10.1007/s10530-012-0202-4

Donaldson JE, Richardson DM, Wilson JR (2014) Scale-area curves: a tool for understanding the ecology and distribution of invasive tree species. Biological invasions 16: 553–563. doi: 10.1007/s10530-013-0602-0

Duke JA (1983) *Acacia mearnsii*. Handbook of Energy Crops. Unpublished.

Feng Y, Dong X, Hu R, Ke Q, Ding B (2010) Study on risk evaluation system for alien invasive plants in Wenzhou: taking *Acacia mearnsii* for an example. Journal of Plant Resources and Environment 19: 79–84. doi: 10.3875/j.issn.1674-3563.2011.03.004 [In Chinese]

Fu ZJ (2005) Invasiveness of Two Exotic Tree Species: *Acacia mearnsii* De Wild. and *Acacia dealbata* Link. MSc Thesis. Chinese Academy of Forestry Sciences, Beijing. [In Chinese]

Gao C, Ren H (1989) Division of suitable area for growing wattle, Acacia mearnsii, and key points of planting technique in each area. Forest Research 2: 489–494. doi: 10.13275/j.cnki.lykxyj.1989.05.012 [In Chinese]

Gallagher RV, Leishman MR, Miller JT, Hui C, Richardson DM, Suda J, Trávníček P (2011) Invasiveness in introduced Australian acacias: the role of species traits and genome size. Diversity and Distributions 17: 884–897. doi: 10.1111/j.1472-4642.2011.00805.x

Gibson MR, Richardson DM, Marchante E, Marchante H, Rodger JG, Stone GN, Byrne M, Fuentes-Ramírez A, George N, Harris C (2011) Reproductive biology of Australian acacias: important mediator of invasiveness? Diversity and Distributions 17: 911–933. doi: 10.1111/j.1472-4642.2011.00808.x

Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=51&fr=1&sts=sss&lang=EN

Ke QQ, Nan KW, Zheng SS, Feng YY, Hu RY, Ding BY (2010) Community feature and species diversity of *Acacia mearnsii* communities in Wenzhou. Journal of Zhejiang University (Science Edition) 3: 018. doi: 10.3785/j.issn.1008-9497.2010.03.017 [In Chinese]

Lamarque LJ, Delzon S, Lortie CJ (2011) Tree invasions: a comparative test of the dominant hypotheses and functional traits. Biological invasions 13: 1969–1989. doi: 10.1007/s10530-011-0015-x

Li J (2014) A Preliminary Study on the Relationships Among Birds, Plants and Insects at Kunming Changshui Airport. MSc Thesis. Yunnan University. [In Chinese]

Li L, Luo Z, Li Q (2007) Species competition and dynamics in the communities invaded by Black Wattle in Wenzhou. Acta Ecologica Sinica 29: 6622–6629. doi: 10.3321/j.issn:1000-0933.2009.12.038 [In Chinese]

Li X, Huang Y, Huang W, Zhou J (2011) Landscape analysis of roost trees for common birds in Kunming city. Journal of Nanjing Forestry University (Natural Sciences Edition) 5: 59–63. doi: 10.3969/j.jssn.1000-2006.2011.05.013 [In Chinese]

Li X, Zhou C, Jing W, Wan Q, Huang Y, Fang Y (2010) Airport vegetation management and birdstrike disasters avoidance. Journal of Safety Science and Technology 1: 78–82. doi: 10.3969/j.issn.1673-193X.2010.01.017 [In Chinese]

Liao JT, Zhao XB, Hu SJ, Xu YZ (2012) Avianspatial and temporal changes and bird strike preventive measures at Kunming Wujiaba international airport [J]. Journal of Anhui University (Natural Science Edition) 2: 95–102. doi: 10.3969/j.issn.1000-2162.2012.02.017 [In Chinese]

Low T (2012) Australian acacias: weeds or useful trees? Biological invasions 14: 2217–2227. doi: 10.1007/s10530-012-0243-8

Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the world's worst invasive alien species: a selection from the global invasive species database. Invasive Species Specialist Group Auckland, New Zealand.

Luque GM, Bellard C, Bertelsmeier C, Bonnaud E, Genovesi P, Simberloff D, Courchamp F (2014) The 100th of the world's worst invasive alien species. Biological invasions 16: 981–985. doi: 10.1007/s10530-013-0561-5

Pyšek P, Richardson DM, Rejmánek M, Webster GL, Williamson M, Kirschner J (2004) Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon: 131–143. doi: 10.2307/4135498

Richardson DM, Carruthers J, Hui C, Impson FA, Miller JT, Robertson MP, Rouget M, Le Roux JJ, Wilson JR (2011) Human-mediated introductions of Australian acacias– a global experiment in biogeography. Diversity and Distributions 17: 771–787. doi: 10.1111/j.1472-4642.2011.00824.x

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD, West CJ (2000) Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6: 93–107. doi: 10.1046/j.1472-4642.2000.00083.x

Sandström U, Angelstam P, Mikusiński G (2006) Ecological diversity of birds in relation to the structure of urban green space. Landscape and Urban Planning 77: 39–53. doi: 10.1016/j.landurbplan.2005.01.004

Sherry SP (1971) The Black Wattle (*Acacia mearnsii* De Wild.).

Tilghman NG (1987) Characteristics of urban woodlands affecting breeding bird diversity and abundance. Landscape and Urban Planning 14: 481–495. doi: 10.1007/s11252-014-0433-5

van Wilgen BW, Richardson DM (2014) Challenges and trade-offs in the management of invasive alien trees. Biological invasions 16: 721–734. doi: 10.1007/s10530-013-0615-8

Xu Y, Liao J, Zhenn Y, Zhang F, Wang Z, Zhang L, Ou X (2011) Assessment of plant diversity and the birds' suitability in Kunming airport. Journal of Safety Science and Technology 7: 135–140. doi: 10.3969/j.issn.1673-193X.2011.08.024 [In Chinese]